

Docket No. RSW920000182US1

**METHOD AND SYSTEM FOR SAMPLE DATA SELECTION TO TEST AND  
TRAIN PREDICTIVE ALGORITHMS OF CUSTOMER BEHAVIOR**

**CROSS REFERENCE TO RELATED APPLICATIONS**

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The present invention is related to the following applications entitled "METHOD AND SYSTEM FOR INTEGRATING SPATIAL ANALYSIS AND DATA MINING ANALYSIS TO ASCERTAIN FAVORABLE POSITIONING OF PRODUCTS IN A RETAIL ENVIRONMENT", U.S. Application Serial Number \_\_\_\_\_, Attorney Docket Number CR9-99-049; "METHOD AND SYSTEM FOR INTEGRATING SPATIAL ANALYSIS AND DATA MINING ANALYSIS TO ASCERTAIN WARRANTY ISSUES ASSOCIATED WITH TRANSPORTATION PRODUCTS", U.S. Application Serial Number \_\_\_\_\_, Attorney Docket Number CR9-99-050; and "METHOD AND SYSTEM FOR INTEGRATING SPATIAL ANALYSIS AND DATA MINING ANALYSIS TO ASCERTAIN RELATIONSHIPS BETWEEN COLLECTED SAMPLES AND GEOLOGY WITH REMOTELY SENSED DATA", U.S. Application Serial Number \_\_\_\_\_, Attorney Docket Number CR9-99-051; all of which were filed \_\_\_\_\_, and "METHOD AND SYSTEM FOR INTEGRATING SPATIAL ANALYSIS, DATA MINING ANALYSIS, AND SCHEDULING TO EFFICIENTLY SCHEDULE AND MONITOR INFRASTRUCTURE MAINTENANCE", U.S. Application Serial Number \_\_\_\_\_, Attorney Docket Number RSW9-2000-0051-US1, filed on \_\_\_\_\_, all of which are assigned to the same assignee, and incorporated herein by reference.

## BACKGROUND OF THE INVENTION

### 1. Technical Field:

5       The present invention relates to an improved data processing system. In particular, the present invention relates to a method and system for selecting sample data to test and train predictive algorithms of customer behavior.

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### 2. Description of Related Art:

15       Currently, when using artificial intelligence algorithms to discover patterns in behavior exhibited by customers, it is necessary to create training data sets where a predicted outcome is known as well as testing data sets where the predicted outcome is known to be able to validate the accuracy of a predictive algorithm. The predictive algorithm, for example, may be designed to predict a customer's propensity to respond to an offer or his propensity to buy a product.

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25       The data used to train and test the algorithm are selected using a random selection procedure, such as selecting data based upon a random number generator, or by some other means to insure that both the training data and test data sets are representative of the entire data population being evaluated. Tests of randomness of each of the attributes, e.g., the demographic information of the individuals, in the data sets can then be completed to see if they represent a randomly selected population.

Docket No. RSW920000182US1

While the above approach to selecting testing and training data sets may be suited for some applications, the purchasing behavior of customers is not only based on demographic and cyclographic information. Rather,  
5 geographic locations also influence a customer's purchasing behavior.

People tend to co-locate based on common interests and common backgrounds. That is, people tend to co-locate with other persons with which they have common  
10 characteristics. This effect is known as the "nugget" effect. In much the same way that gold, due to its inert chemistry is rarely evenly distributed through rock and is thus, found in nuggets within a particular geographic formation, people also tend to "nugget" in geographical  
15 areas. Such "nuggeting" of individuals is not taken into consideration when selecting training and testing data for a predictive algorithm in the known systems. Thus, bias may be introduced into either the test data, train data, or both data sets making either or both  
20 nonrepresentative of the overall customer database.

Therefore, it would be beneficial to have a method and system for selecting a data sample for testing, training and using discovery based data mining in a customer relationship marketing predictive system which  
25 takes into consideration any geographic bias that may exist in the original customer database and/or in the selected data samples.

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**SUMMARY OF THE INVENTION**

5 The present invention provides a method and system  
for sample data selection to test and train predictive  
algorithms of customer behavior. The method and system  
generate frequency distributions of a customer database  
data set, training data set and testing data set and  
compare the frequency distributions of geographical  
10 characteristics to determine if there are discrepancies.  
If the discrepancies are above a predetermined tolerance,  
one or more of the data sets may not be representative of  
the customer database taking into account geographical  
influences on customer behavior. Thus, recommendations  
15 for improving the training data set and/or testing data  
set are then provided such that the data set is more  
representative of the customer database. In this way,  
"nuggeting" of customers is accounted for in the training  
and/or testing data sets.

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**BRIEF DESCRIPTION OF THE DRAWINGS**

5 The novel features believed characteristic of the invention are set forth in the appended claims. The invention itself, however, as well as a preferred mode of use, further objectives and advantages thereof, will best be understood by reference to the following detailed description of an illustrative embodiment when read in  
10 conjunction with the accompanying drawings, wherein:

**Figure 1** depicts a pictorial representation of a distributed data processing system in which the present invention may be implemented;

**Figure 2** is a block diagram illustrating a server  
15 data processing system in which the present invention may be implemented;

**Figure 3** is an exemplary block diagram of a client device in accordance with the present invention;

**Figure 4** is an exemplary diagram that depicts a  
20 process of obtaining test and training data from a customer database;

**Figure 5A** is a block diagram depicting a data flow between the elements that may be used to select testing and training data sets in accordance with the present  
25 invention;

**Figure 5B** represents an exemplary training data set frequency diagram in accordance with the present invention;

**Figure 5C** represents an exemplary testing data set frequency diagram in accordance with the present invention; and

**Figure 6** is a flowchart depicting a process for  
5 test/train data set selection for use with discovery  
based data mining in customer relationship marketing.

**DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT**

With reference now to the figures, **Figure 1** depicts  
5 a pictorial representation of a distributed data  
processing system in which the present invention may be  
implemented. Distributed data processing system **100** is a  
network of computers in which the present invention may  
be implemented. Distributed data processing system **100**  
10 contains a network **102**, which is the medium used to  
provide communications links between various devices and  
computers connected together within distributed data  
processing system **100**. Network **102** may include permanent  
connections, such as wire or fiber optic cables, or  
15 temporary connections made through telephone connections.

In the depicted example, a server **104** is connected  
to network **102** along with storage unit **106**. In addition,  
clients **108**, **110**, and **112** also are connected to a network  
**102**. These clients **108**, **110**, and **112** may be, for  
20 example, personal computers, customer behavior prediction  
devices, or the like. In the depicted example, server  
**104** provides data, such as boot files, operating system  
images, and applications to clients **108-112**. Clients  
**108**, **110**, and **112** are clients to server **104**. Distributed  
25 data processing system **100** may include additional  
servers, clients, and other devices not shown. In the  
depicted example, distributed data processing system **100**  
is the Internet with network **102** representing a worldwide

Docket No. RSW920000182US1

collection of networks and gateways that use the TCP/IP suite of protocols to communicate with one another. At the heart of the Internet is a backbone of high-speed data communication lines between major nodes or host computers, consisting of thousands of commercial, government, educational and other computer systems that route data and messages. Of course, distributed data processing system 100 also may be implemented as a number of different types of networks, such as for example, an intranet, a local area network (LAN), or a wide area network (WAN). **Figure 1** is intended as an example, and not as an architectural limitation for the present invention.

The present invention provides a method and apparatus for evaluating the selection of test and train data to determine if the test and train data accurately represent a geographical distribution of customers in a customer database. The present invention makes use of customer data that may be obtained from one or more sources in a distributed data processing system, such as distributed data processing system 100. For example, customer data may be obtained from retailer databases, third party data providers, and the like, which may be located remotely but accessible through the network 102.

The present invention may be implemented in a client device or a server. For example, the present invention may be implemented in a server, such as server 104, that obtains customer data from the various sources via the



Docket No. RSW920000182US1

network 102. In response to a request from a client device, such as client device 112, the server 104 may evaluate test and train data for a predictive algorithm and provide guidance as to how to better select the test and train data to adjust the test and train data to be more geographically representative of the customer database.

Referring to **Figure 2**, a block diagram of a data processing system that may be implemented as a server, such as server 104 in **Figure 1**, is depicted in accordance with a preferred embodiment of the present invention. Data processing system 200 may be a symmetric multiprocessor (SMP) system including a plurality of processors 202 and 204 connected to system bus 206. Alternatively, a single processor system may be employed. Also connected to system bus 206 is memory controller/cache 208, which provides an interface to local memory 209. I/O bus bridge 210 is connected to system bus 206 and provides an interface to I/O bus 212. Memory controller/cache 208 and I/O bus bridge 210 may be integrated as depicted.

Peripheral component interconnect (PCI) bus bridge 214 connected to I/O bus 212 provides an interface to PCI local bus 216. A number of modems may be connected to PCI bus 216. Typical PCI bus implementations will support four PCI expansion slots or add-in connectors. Communications links to network computers 108-112 in **Figure 1** may be provided through modem 218 and network

Docket No. RSW920000182US1

adapter 220 connected to PCI local bus 216 through add-in boards.

Additional PCI bus bridges 222 and 224 provide interfaces for additional PCI buses 226 and 228, from which additional modems or network adapters may be supported. In this manner, data processing system 200 allows connections to multiple network computers. A memory-mapped graphics adapter 230 and hard disk 232 may also be connected to I/O bus 212 as depicted, either directly or indirectly.

Those of ordinary skill in the art will appreciate that the hardware depicted in **Figure 2** may vary. For example, other peripheral devices, such as optical disk drives and the like, also may be used in addition to or in place of the hardware depicted. The depicted example is not meant to imply architectural limitations with respect to the present invention.

The data processing system depicted in **Figure 2** may be, for example, an IBM RISC/System 6000 system, a product of International Business Machines Corporation in Armonk, New York, running the Advanced Interactive Executive (AIX) operating system.

With reference now to **Figure 3**, a block diagram illustrating a data processing system is depicted in which the present invention may be implemented. Data processing system 300 is an example of a client computer. Data processing system 300 employs a peripheral component interconnect (PCI) local bus architecture. Although the

depicted example employs a PCI bus, other bus architectures such as Accelerated Graphics Port (AGP) and Industry Standard Architecture (ISA) may be used.

Processor 302 and main memory 304 are connected to PCI

5 local bus 306 through PCI bridge 308. PCI bridge 308 also may include an integrated memory controller and cache memory for processor 302. Additional connections to PCI local bus 306 may be made through direct component interconnection or through add-in boards. In the

10 depicted example, local area network (LAN) adapter **310**,  
SCSI host bus adapter **312**, and expansion bus interface  
**314** are connected to PCI local bus **306** by direct

component connection. In contrast, audio adapter **316**, graphics adapter **318**, and audio/video adapter **319** are

15 connected to PCI local bus 306 by add-in boards inserted  
into expansion slots. Expansion bus interface 314

provides a connection for a keyboard and mouse adapter **320**, modem **322**, and additional memory **324**. Small computer system interface (SCSI) host bus adapter **312**

20 provides a connection for hard disk drive **326**, tape drive **328**, and CD-ROM drive **330**. Typical PCI local bus implementations will support three or four PCI expansion slots or add-in connectors.

An operating system runs on processor 302 and is used to coordinate and provide control of various components within data processing system 300 in **Figure 3**. The operating system may be a commercially available operating system, such as Windows 2000, which is

Docket No. RSW920000182US1

available from Microsoft Corporation. An object oriented programming system such as Java may run in conjunction with the operating system and provide calls to the operating system from Java programs or applications  
5 executing on data processing system 300. "Java" is a trademark of Sun Microsystems, Inc. Instructions for the operating system, the object-oriented operating system, and applications or programs are located on storage devices, such as hard disk drive 326, and may be loaded  
10 into main memory 304 for execution by processor 302.

Those of ordinary skill in the art will appreciate that the hardware in **Figure 3** may vary depending on the implementation. Other internal hardware or peripheral devices, such as flash ROM (or equivalent nonvolatile  
15 memory) or optical disk drives and the like, may be used in addition to or in place of the hardware depicted in **Figure 3**. Also, the processes of the present invention may be applied to a multiprocessor data processing system.

20 As another example, data processing system 300 may be a stand-alone system configured to be bootable without relying on some type of network communication interface, whether or not data processing system 300 comprises some type of network communication interface. As a further  
25 example, data processing system 300 may be a Personal Digital Assistant (PDA) device, which is configured with ROM and/or flash ROM in order to provide non-volatile memory for storing operating system files and/or

Docket No. RSW920000182US1

user-generated data.

The depicted example in **Figure 3** and above-described examples are not meant to imply architectural limitations. For example, data processing system 300  
5 also may be a notebook computer or hand held computer in addition to taking the form of a PDA. Data processing system 300 also may be a kiosk or a Web appliance.

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10 The present invention provides a system and method for evaluating the geographical distributions of test and train data samples to provide a qualitative view of sampling bias. With the present invention, distributions of test and train data sets are identified and compared with each other and with a distribution of the entire customer database in order to ascertain randomness of the  
15 selection of the test and train data sets. The randomness of the selection of the test and train data sets with regard to geography may be ascertained by assessing the distribution of the distance of the customers from the commercial establishment or the time  
20 to travel to the commercial establishment from the customers' homes and work locations. If the normality of this distribution is compared with the test and train distributions, the representativeness of the three data sets, i.e. test, train and complete customer database,  
25 may be compared. By comparing the mean, mode, and standard deviation plus plotting the data on a frequency distribution diagram to look at data distribution of distance or travel time to a commercial establishment in all three data sets, a determination as to whether the

Docket No. RSW920000182US1

data sets are representative of the customer population may be made.

Finally, if there are competing commercial establishments a weighted distance calculation may be made for each of the customers to ensure that the distribution of the customers in either data set is not biased with reference to competitors or with the commercial establishment of interest. An easy way of establishing this relationship is to use the drive time calculation as shown in the formula:  $(((\text{Drive Time to establishment of choice (DTE)}) / (\text{DTE} + \text{DT1} + \text{DT2} \dots \text{DTN})) \times 100$ , where DT1, DT2... are the drive times to competitor commercial establishments. The frequency distribution of these weighted drive times may be compared in the same way as the individual drive time calculations where there is no specific identified competitor.

By testing for representative location parameters in these data sets when training the predictive algorithm, a more accurate predictive algorithm may be obtained for predicting customer behaviors. This is because often times geography may override other factors in customer decisions that may be modeled using demographic information. For example, although a customer may have a demographic profile that indicates the customer is a good candidate for marketing a product from a commercial establishment, the travel distance or travel time for the customer candidate to arrive at the commercial establishment may be such that the customer candidate is

Docket No. RSW920000182US1

disuaded from traveling to the commercial establishment to purchase the product. Thus, the geographical influence overrides the demographic influences. Such contention between geographic and demographic influences is not taken into consideration in known systems when selecting training and testing data sets.

**Figure 4** is an exemplary block diagram illustrating a process of initially selecting test and train data for a predictive algorithm, such as a discovery based data mining algorithm. As shown in **Figure 4**, a set of customers **400** for which information has been obtained are present in a geographical area. These customers **400** are geographically located in clusters due to their natural affiliation with other persons having the same backgrounds, both demographic and cyclographic. From these customers **400** a customer database is generated **410**. The customer database **410** may be generated, for example, by sending questionnaires to the customers and compiling responses from the customers **400**, for example. Similarly, customer database **410** may be generated based on product warranty information submitted by the various customers. Alternatively, the customer database **410** may be obtained from publicly available information from various governmental or commercial sources. Other mechanisms for compiling and storing the customer database **410** may be used without departing from the spirit and scope of the present invention.

From the customer database **410**, a set of training

Docket No. RSW920000182US1

data 420 and testing data 430 are generated. In known systems, these sets of data 420 and 430 are generated using a random selection process, as previously described. Based on this random selection process, various ones of the customers in the customer database 410 are selected for inclusion into the training data set 420 and the testing data set 430.

As can be seen from Figure 4, by selecting customers randomly from the customer database 410, it is possible that some of the clusters of customers may not be represented in the training and testing data sets 420 and 430. Moreover, the training data set 420 and the testing data set 430 may not be commonly representative of the same clusters of customers. In other words, the training data set 420 may contain customers from clusters 1 and 3 while the testing data set 430 may contain customers selected from clusters 1 and 2.

Because of the discrepancies between the training and testing data sets 420 and 430 with the customer database 410, and because people tend to cluster together in groups having similar demographic profiles, certain types of customers may be over-represented and other types of customers may be under-represented. As a result, the predictive algorithm may not accurately represent the behavior of potential customers.

Moreover because of the discrepancies between the training and testing data sets 420 and 430, the predictive algorithm may be trained improperly. That is,



Docket No. RSW920000182US1

the training data set 420 may train the predictive algorithm to output a particular predicted customer behavior based on a particular input. However, the testing data set 430 may indicate a different customer behavior based on the same input due to the differences in the customer clusters represented in the training data set 420 and the testing data set 430.

For example, as shown in Figure 4, the training data set 420 is predominately comprised of customers from clusters A, B and C. Assume that customers in clusters A and B are very good customer candidates for a new electronic items while customers in group C are only mildly good customer candidates for new electronic items. Based on this training data, if a commercial establishment at location X were interested in introducing a new electronic item, the predictive algorithm may indicate that there is a high likelihood of customer demand for the new electronic item from customers in clusters A and B. Thus, the commercial establishment may concentrate advertising in these geographical locations.

However, in actuality, assume that customers in clusters A and B are less likely to travel from their location to the location X due to the geographical obstacle (mountains) and travel time required. Thus, the predictive algorithm will provide an erroneous result costing the commercial establishment advertising money that could have been used otherwise.

Docket No. RSW920000182US1

Moreover, if the testing data contains customers from clusters A, B, D and E, the customer behaviors in the testing data will be different from that of customers in the training data set (comprising clusters A, B and C). As a result, the testing data and the training data are not consistent and erroneous customer behavior predictions will arise. Thus, geographic effects of clustering must be taken into account when selecting customers to be included in training and testing data sets of a customer behavior predictive algorithm.

With the present invention, the discrepancies between a testing data set and a training data set are identified. Furthermore, the discrepancies between both the testing data set and the training data set and the customer database are identified. The discrepancies are identified based on a geographical characteristic such as distance or drive time. The normalized frequency distributions of distance and/or drive time of customers in the training data set are compared to the normalized frequency distributions of the testing data set. If the differences between the frequency distributions is above a predetermined tolerance, the two data sets are too different to provide accurate training of the predictive algorithm when taking geographical influences into account. This same procedure may be performed with regard to the frequency distribution of the customer database.

In order to compare the frequency distributions, the mean, mode and/or standard deviations of the frequency

Docket No. RSW920000182US1

distributions may be compared with one another to determine if the frequency distributions are similar within a predetermined tolerance. The mean is a representation of the average of the frequency  
5 distribution. The mode is a representation of the most frequently occurring value in the data set. The standard deviation is a measure of dispersion in a set of data. Based on these quantities for each frequency distribution, a comparison of the frequency  
10 distributions may be made to determine if they adequately represent the customer population clusters in the customer database. If they do not, the present invention may, based on the relative discrepancies of the various data sets, make recommendations as to how to better  
15 select training and testing data sets that represent the geographic clustering of customers.

For example, if the relative discrepancy between a testing data set and a training data set are such that the training data set does not contain enough customers  
20 to represent all of the necessary clusters in the testing data set, the training data set may need to be increased in size. Similarly, if the testing data set and/or training data set do not contain enough customers to represent all of the clusters in the customer database,  
25 the testing and training data sets may need to be increased. In such cases, the same random selection algorithm may be used and the same seed value of the random selection algorithm may be used with the number of customers selected being increased.

Docket No. RSW920000182US1

Moreover, the testing data set and training data sets may be combined to form a composite data set which may be compared to the customer database. In combining the two data sets, customers appearing in a first data set, and not in the second data set, are added to the composite data set, and vice versa.

The frequency distribution of the composite data set may be compared to the frequency distribution of the customer database, in the manner described above, to determine if the composite represents the customer clusters appropriately. If the composite data set does represent the customer clusters of the customer database appropriately, the composite data set may be used to train the predictive algorithm. If the composite data set does not represent the customer clusters of the customer database appropriately, a new random selection algorithm may need to be used or a new seed value of a random selection algorithm may need to be used. In this way, the selection of training and testing data is modified such that the training and testing data better represents actual customer behavior based on geographical influences.

In a preferred embodiment of the present invention, the predictive algorithm is a discovery based data mining algorithm that is used to identify relationships between data. Data mining is an efficient mechanism for the discovery of valuable, non-obvious information from a large collection of data and centers on the automated discovery of new facts and underlying relationships in

Docket No. RSW920000182US1

the data. The term "data mining" comes from the idea that the raw material is the business data, and the data mining algorithm is the excavator, shifting through the vast quantities of raw data looking for the valuable  
5 nuggets of business information.

As a preferred embodiment of the present invention relies on the relatively new field of data mining and uses data mining algorithms, although other types of predictive algorithms may be used without departing from  
10 the spirit and scope of the present invention. In order to aid in the understanding of how geographic representation is important to predictive algorithms, and in particular to data mining, a discussion of the general techniques and purposes of data mining are herein  
15 provided.

#### **Background on Data Mining**

Data mining is a process for extracting  
20 relationships in data stored in database systems. As is well-known, users can query a database system for low-level information, such as an amount of money spent by a particular customer at a commercial establishment during the last month. Data mining systems, on the other  
25 hand, can build a set of high-level rules about a set of data, such as "If the customer is a white collar employee, and the age of the customer is over 30 years, and the amount of money spent by the customer on video games last year was above \$100.00, then the probability  
30 that the customer will buy a video game in the next month

Docket No. RSW920000182US1

is greater than 60%." These rules allow an owner/operator of a commercial establishment to better understand the relationship between employment, age and prior spending habits and allows the owner/operator to

5 make queries, such as "Where should I direct may direct mail advertisements?" This type of knowledge allows for targeted marketing and helps to guide other strategic decisions. Other applications of data mining include finance, market data analysis, medical diagnosis,

10 scientific tasks, VLSI design, analysis of manufacturing processes, etc. Data mining involves many aspects of computing, including, but not limited to, database theory, statistical analysis, artificial intelligence, and parallel/distributed computing.

15 Data mining may be categorized into several tasks, such as association, classification, and clustering. There are also several knowledge discovery paradigms, such as rule induction, instance-based learning, neural networks, and genetic algorithms. Many combinations of

20 data mining tasks and knowledge discovery paradigms are possible within a single application.

#### **Data Mining Tasks**

25 An association rule can be developed based on a set of data for which an attribute is determined to be either present or absent. For example, suppose data has been collected on a set of customers and the attributes are age and number of video games purchased last year. The

Docket No. RSW920000182US1

goal is to discover any association rules between the age of the customer and the number of video games purchased.

Specifically, given two non-intersecting sets of items, e.g., sets X and Y, one may attempt to discover  
5 whether there is a rule "if X is 18 years old, then Y is 3 or more video games," and the rule is assigned a measure of support and a measure of confidence that is equal or greater than some selected minimum levels. The measure of support is the ratio of the number of records  
10 where X is 18 years old and Y is 3 or more video games, divided by the total number of records. The measure of confidence is the ratio of the number of records where X is 18 years old and Y is 3 or more video games, divided by the number of records where X is 18 years old. Due to  
15 the smaller number of records in the denominators of these ratios, the minimum acceptable confidence level is higher than the minimum acceptable support level.

Returning to video game purchases as an example, the minimum support level may be set at 0.3 and the minimum  
20 confidence level set at 0.8. An example rule in a set of video game purchase information that meets these criteria might be "if the customer is 18 years old, then the number of video games purchased last year is 3 or more."

Given a set of data and a set of criteria, the  
25 process of determining associations is completely deterministic. Since there are a large number of subsets possible for a given set of data and a large amount of information to be processed, most research has focused on developing efficient algorithms to find all associations.

Docket No. RSW920000182US1

However, this type of inquiry leads to the following question: Are all discovered associations really significant? Although some rules may be interesting, one finds that most rules may be uninteresting since there is  
5 no cause and effect relationship. For example, the association "if the customer is 18 years old, then the number of video games purchased last year is 3 or more" would also be a reported association with exactly the same support and confidence values as the association "if  
10 the number of video games purchase is 3 or more, then the age of the customer is 18 years old."

Classification tries to discover rules that predict whether a record belongs to a particular class based on the values of certain attributes. In other words, given  
15 a set of attributes, one attribute is selected as the "goal," and one desires to find a set of "predicting" attributes from the remaining attributes. For example, suppose it is desired to know whether a particular customer will purchase a video game within the next  
20 month. For example, a rather trivial example of this type of rule could include "If the customer is 18 years old, there is a 25% chance the customer will purchase a video game within the next month."

A set of data is presented to the system based on  
25 past knowledge. This data "trains" the system. The present invention provides a mechanism by which such training data may be selected in order to better conform with actual customer behavior taking into account geographic influences. The goal is to produce rules that



Docket No. RSW920000182US1

will predict behavior for a future class of data. The main task is to design effective algorithms that discover high quality knowledge. Unlike an association in which one may develop definitive measures for support and confidence, it is much more difficult to determine the quality of a discovered rule based on classification.

A problem with classification is that a rule may, in fact, be a good predictor of actual behavior but not a perfect predictor for every single instance. One way to overcome this problem is to cluster data before trying to discover classification rules. To understand clustering, consider a simple case where two attributes are considered: age and number of video games purchased last year. These data points can be plotted on a two-dimensional graph. Given this plot, clustering is an attempt to discover or "invent" new classes based on groupings of similar records. For example, for the above attributes, a clustering of data in the range of 17-20 years old for customer age might be found for 1-4 video games purchased last year. This cluster could then be treated as a single class.

Clusters of data represent subsets of data where members behave similarly but not necessarily the same as the entire population. In discovering clusters, all attributes are considered equally relevant. Assessing the quality of discovered clusters is often a subjective process. Clustering is often used for data exploration and data summarization.

### Knowledge Discovery Paradigms

There are a variety of knowledge discovery  
5 paradigms, some guided by human users, e.g. rule  
induction and decision trees, and some based on AI  
techniques, e.g. neural networks. The choice of the most  
appropriate paradigm is often application dependent.

On-line analytical processing (OLAP) is a  
10 database-oriented paradigm that uses a multidimensional  
database where each of the dimensions is an independent  
factor, e.g., customer vs. video games purchased vs.  
income level. There are a variety of operators provided  
that are most easily understood if one assumes a  
15 three-dimensional space in which each factor is a  
dimension of a vector within a three-dimensional cube.  
One may use "pivoting" to rotate the cube to see any  
desired pair of dimensions. "Slicing" involves a subset  
of the cube by fixing the value of one dimension.  
20 "Roll-up" employs higher levels of abstraction, e.g.  
moving from video games bought-by-age to video games  
bought-by-income level, and "drill-down" goes to lower  
levels, e.g. moving from video games bought-by-age to  
video games bought-by-gender.

25 The Data Cube operation computes the power set of  
the "Group by" operation provided by SQL. For example,  
given a three dimension cube with dimensions A, B, C,  
then Data Cube computes Group by A, Group by B, Group by  
C, Group by A,B, Group by A,C, Group by B,C, and Group by

Docket No. RSW920000182US1

A,B,C. OLAP is used by human operators to discover previously undetected knowledge in the database.

Recall that classification rules involve predicting attributes and the goal attribute. Induction on  
5 classification rules involves specialization, i.e. adding a condition to the rule antecedent, and generalization, i.e. removing a condition from the antecedent. Hence, induction involves selecting what predicting attributes will be used. A decision tree is built by selecting the  
10 predicting attributes in a particular order, e.g., customer age, video games purchased last year, income level.

The decision tree is built top-down assuming all records are present at the root and are classified by  
15 each attribute value going down the tree until the value of the goal attribute is determined. The tree is only as deep as necessary to reach the goal attribute. For example, if no customers of age 2 bought video games last year, then the value of the goal attribute "number of  
20 video games purchase last year?" would be determined (value equals "0") once the age of the customer is known to be 2. However, if the age of the customer is 7, it may be necessary to look at other predicting attributes to determine the value of the goal attribute. A human is  
25 often involved in selecting the order of attributes to build a decision tree based on "intuitive" knowledge of which attribute is more significant than other attributes.

Docket No. RSW920000182US1

Decision trees can become quite large and often require pruning, i.e. cutting off lower level subtrees. Pruning avoids "overfitting" the tree to the data and simplifies the discovered knowledge. However, pruning  
5 too aggressively can result in "underfitting" the tree to the data and missing some significant attributes.

The above techniques provide tools for a human to manipulate data until some significant knowledge is discovered and removes some of the human expert knowledge  
10 interference from the classification of values. Other techniques rely less on human intervention.

Instance-based learning involves predicting the value of a tuple, e.g., predicting if someone of a particular age and gender will buy a product, based on stored data for  
15 known tuple values. A distance metric is used to determine the values of the N closest neighbors, and these known values are used to predict the unknown value.

The final technique examined is neural nets. A typical neural net includes an input layer of neurons  
20 corresponding to the predicting attributes, a hidden layer of neurons, and an output layer of neurons that are the result of the classification. For example, there may be eight input neurons corresponding to "under 3 video games purchase last year", "between 3 and 6 video games  
25 purchase last year ", "over 6 video games purchased last year", "in Plano, Texas", "customer age below 10 years old", "customer age above 18 years old", and "customer age between 10 and 18 years old." There could be two output neurons: "will purchase video game within next

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Docket No. RSW920000182US1

month" and "will not purchase video game within next month". A reasonable number of neurons in the middle layer is determined by experimenting with a particular known data set.

5        There are interconnections between the neurons at adjacent layers that have numeric weights. When the network is trained, meaning that both the input and output values are known, these weights are adjusted to give the best performance for the training data. The  
10    "knowledge" is very low level (the weight values) and is distributed across the network. This means that neural nets do not provide any comprehensible explanation for their classification behavior—they simply provide a predicted result.

15        Neural nets may take a very long time to train, even when the data is deterministic. For example, to train a neural net to recognize an exclusive-or relationship between two Boolean variables may take hundreds or thousands of training data (the four possible  
20    combinations of inputs and corresponding outputs repeated again and again) before the neural net learns the circuit correctly. However, once a neural net is trained, it is very robust and resilient to noise in the data. Neural nets have proved most useful for pattern recognition  
25    tasks, such as recognizing handwritten digits in a zip code.

Other knowledge discovery paradigms can be used, such as genetic algorithms. However, the above discussion presents the general issues in knowledge

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Docket No. RSW920000182US1

discovery. Some techniques are heavily dependent on human guidance while others are more autonomous. The selection of the best approach to knowledge discovery is heavily dependent on the particular application.

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### **Data Warehousing**

The above discussions focused on data mining tasks and knowledge discovery paradigms. There are other  
10 components to the overall knowledge discovery process.

Data warehousing is the first component of a knowledge discovery system and is the storage of raw data itself. One of the most common techniques for data  
15 warehousing is a relational database. However, other techniques are possible, such as hierarchical databases or multidimensional databases. No matter which type of database is used, it should be able to store points, lines, and polygons such that geographic distributions can be assessed. This type of warehouse or database is  
20 sometimes referred to as a spatial data warehouse.

Data is nonvolatile, i.e. read-only, and often includes historical data. The data in the warehouse needs to be "clean" and "integrated". Data is often  
25 taken from a wide variety of sources. To be clean and integrated means data is represented in a consistent, uniform fashion inside the warehouse despite differences in reporting the raw data from various sources.

There also has to be data summarization in the form of a high level aggregation. For example, consider a

Docket No. RSW920000182US1

phone number 111-222-3333 where 111 is the area code, 222 is the exchange, and 3333 is the phone number. The telephone company may want to determine if the inbound number of calls is a good predictor of the outbound number of calls. It turns out that the correlation between inbound and outbound calls increases with the level of aggregation. In other words, at the phone number level, the correlation is weak but as the level of aggregation increases to the area code level, the correlation becomes much higher.

### **Data Pre-processing**

After the data is read from the warehouse, it is pre-processed before being sent to the data mining system. The two pre-processing steps discussed below are attribute selection and attribute discretization.

Selecting attributes for data mining is important since a database may contain many irrelevant attributes for the purpose of data mining, and the time spent in data mining can be reduced if irrelevant attributes are removed beforehand. Of course, there is always the danger that if an attribute is labeled as irrelevant and removed, then some truly interesting knowledge involving that attribute will not be discovered.

If there are  $N$  attributes to choose between, then there are  $2^N$  possible subsets of relevant attributes. Selecting the best subset is a nontrivial task. There are two common techniques for attribute selection. The

Docket No. RSW920000182US1

filter approach is fairly simple and independent of the data mining technique being used. For each of the possible predicting attributes, a table is made with the predicting attribute values as rows, the goal attribute values as columns, and the entries in the table as the number of tuples satisfying the pairs of values. If the table is fairly uniform or symmetric, then the predicting attribute is probably irrelevant. However, if the values are asymmetric, then the predicting attribute may be significant.

The second technique for attribute selection is called a wrapper approach where attribute selection is optimized for a particular data mining algorithm. The simplest wrapper approach is Forward Sequential Selection. Each of the possible attributes is sent individually to the data mining algorithm and its accuracy rate is measured. The attribute with the highest accuracy rate is selected. Suppose attribute 3 is selected; attribute 3 is then combined in pairs with all remaining attributes, i.e., 3 and 1, 3 and 2, 3 and 4, etc., and the best performing pair of attributes is selected.

This hill climbing process continues until the inclusion of a new attribute decreases the accuracy rate. This technique is relatively simple to implement, but it does not handle interaction among attributes well. An alternative approach is backward sequential selection that handles interactions better, but it is computationally much more expensive.



Docket No. RSW920000182US1

Discretization involves grouping data into categories. For example, age in years might be used to group persons into categories such as minors (below 18), young adults (18 to 39), middle-agers (40-59), and senior citizens (60 or above). Some advantages of discretization is that it reduces the time for data mining and improves the comprehensibility of the discovered knowledge. Categorization may actually be required by some mining techniques. A disadvantage of discretization is that details of the knowledge may be suppressed.

Blindly applying equal-weight discretization, such as grouping ages by 10 year cycles, may not produce very good results. It is better to find "class-driven" intervals. In other words, one looks for intervals that have uniformity within the interval and have differences between the different intervals.

#### **Data Post-processing**

The number of rules discovered by data mining may be overwhelming, and it may be necessary to reduce this number and select the most important ones to obtain any significant results. One approach is subjective or user-driven. This approach depends on a human's general impression of the application domain. For example, the human user may propose a rule such as "if a customer's age is less than 18, then the customer has a higher likelihood of purchasing a video game." The discovered

Docket No. RSW920000182US1

rules are then compared against this general impression to determine the most interesting rules. Often, interesting rules do not agree with general expectations. For example, although the conditions are satisfied, the  
 5 conclusion is different than the general expectations. Another example is that the conclusion is correct, but there are different or unexpected conditions.

Rule affinity is a more mathematical approach to examining rules that does not depend on human  
 10 impressions. The affinity between two rules in a set of rules  $\{R_i\}$  is measured and given a numerical affinity value between zero and one, called  $Af(R_x, R_y)$ . The affinity value of a rule with itself is always one, while the affinity with a different rule is less than one.

15 Assume that one has a quality measure for each rule in a set of rules  $\{R_i\}$ , called  $Q(R_i)$ . A rule  $R_j$  is said to be suppressed by a rule  $R_k$  if  $Q(R_j) < Af(R_j, R_k) * Q(R_k)$ .

Notice that a rule can never be suppressed by a lower quality rule since one assumes that  $Af(R_j, R_k) < 1$  if  $j \neq$

20 k. One common measure for the affinity function is the size of the intersection between the tuple sets covered by the two rules, i.e. the larger the intersection, the greater the affinity.

## 25 Data Mining Summary

The discussion above has touched on the following aspects of knowledge processing: data warehousing, pre-processing data, data mining itself, and

Docket No. RSW920000182US1

post-processing to obtain the most interesting and significant knowledge. With large databases, these tasks can be very computationally intensive, and efficiency becomes a major issue. Much of the research in this area  
5 focuses on the use of parallel processing. Issues involved in parallelization include how to partition the data, whether to parallelize on data or on control, how to minimize communications overhead, how to balance the load between various processors, how to automate the  
10 parallelization, how to take advantage of a parallel database system itself, etc.

Many knowledge evaluation techniques involve statistical methods or artificial intelligence or both. The quality of the knowledge discovered is highly  
15 application dependent and inherently subjective. A good knowledge discovery process should be both effective, i.e. discovers high quality knowledge, and efficient, i.e. runs quickly.

**Figure 5A** is an exemplary block diagram depicting a  
20 data flow of an apparatus for selecting training and testing data sets for use with a predictive algorithm, in accordance with a preferred embodiment of the present invention. As shown in **Figure 5**, the apparatus includes a customer database **510**, a training data set/testing data  
25 set selection device **520**, a statistical engine **530**, a comparison engine **540**, and a predictive algorithm **550**. The elements shown in **Figure 5A** may be implemented as software, hardware, or a combination of software and

Docket No. RSW920000182US1

hardware. For example, the elements of **Figure 5A** may be implemented as software instructions executed by a processor, such as processor **202** in **Figure 2**, of a server apparatus. Alternatively, the elements shown in **Figure**  
5 **5A** may be distributed across a plurality of devices such as a client device and one or more server devices.

The customer database **510** provides customer database information to both the training data set/testing data set selection device **520** as well as the statistical  
10 engine **530**. The training data set/testing data set selection device **520** selects a training data set and a testing data set from the customer database information and inputs the training data set and the testing data set to the statistical engine **530**. The testing data set and  
15 training data set may be selected in any known manner. For example, the testing data set and training data set may be selected using a random selection algorithm, or the like.

The statistical engine **530** receives the training  
20 data set, testing data set and customer database information and generates statistical information regarding the frequency distributions of geographical location and/or driving time to a commercial establishment of interest for each data set. Such  
25 information may be, for example, the mean, mode, standard deviation, and the like. The geographical location information and/or driving time may be generated in any known manner, may be obtained from an information

Docket No. RSW920000182US1

supplier via a network, or the like, for example. This frequency distribution information is then output to the comparison engine 540. The mathematical processes for computing frequency distributions, means, modes and standard deviations are generally known in the art.

The comparison engine 540 compares and evaluates the frequency distribution information obtained from the statistical engine 530 to determine if the testing data set and training data sets are geographically representative of the customer population. Such comparison and evaluation may include, for example, determining a difference in frequency distribution information and determining if the difference is beyond a predetermined tolerance. Based on the results of the comparison and evaluation, the comparison engine generates recommendations regarding how to improve the representativeness of the testing data set and training data set. For example, if a difference in the frequency distribution information of the testing and training data sets is beyond a predetermined tolerance, a different seed value for one or both of the algorithms for generating the training and testing data may be selected. If the difference between the frequency distribution information for the training data set and/or the testing data set, and the customer database is beyond a predetermined tolerance, then a new random selection algorithm may be required. Alternatively, as discussed above, a composite data set may be generated and used as a basis for comparison with the customer database

Docket No. RSW920000182US1

frequency distribution information.

If the results of the comparison engine 540 indicate that the training data set and testing data set adequately reflect the geographical distribution of the customer population, the training data set and testing data set may be output to the predictive algorithm 540. **Figures 5B and 5C** represent training and testing data sets in accordance with the present invention.

The predictive algorithm may then use the training data set and testing data set to train itself and generate customer behavior rules. Thereafter, if a user inputs request parameters for requesting a prediction of customer behavior, the customer behavior rules will be applied to the input parameters and a customer behavior prediction will be output.

**Figure 6** is a flowchart outlining an exemplary operation of the present invention. As shown in **Figure 6**, the operation starts with gathering customer database information (step 610). The customer database information is then used as a basis for selecting a training data set and/or testing data set (step 620). Frequency distribution information of geographical location of customers and/or drive time to a commercial establishment of interest is calculated for each of the training data set, testing data set and customer database data set (step 630). The frequency distribution information for each of these data sets is compared and evaluated to determine if differences exceed a

Docket No. RSW920000182US1

predetermined tolerance (step 640).

A determination is made as to whether differences in the frequency distribution information is beyond a predetermined tolerance (step 650). If so,

- 5 recommendations are generated based on the particular differences (step 660) and the operation returns to step 620 where the training and testing data sets are again determined in view of the recommendations. If the differences in frequency distribution information are not  
10 beyond the predetermined tolerance, the training data set and testing data set are used to train the predictive algorithm (step 670) and the operation ends. Thereafter, the predictive algorithm may be used to generate customer behavior predictions taking into account the geographical  
15 influences of customers as represented in the training and testing data sets.

- Thus, the present invention provides a mechanism by which geographical influences on customer behavior may be taken into account when selecting training data and  
20 testing data for training a predictive algorithm of customer behavior. The "nugget" effect of customers co-locating in areas based on common backgrounds is taken into account by comparing the frequency distribution of geographical location of customers and/or drive times to  
25 a commercial establishment of interest in the customer database, training data set and testing data set. By doing so, the present invention ensures that each "nugget" of customers is represented in the training data set and testing data set.

Docket No. RSW920000182US1

The present invention provides a mechanism by which the degree of each "nugget" of customers is represented in the training and testing data sets. For example, if a first nugget of customers has  $x$  number of customers and a second nugget of customers has  $100x$  number of customers, the second nugget will get more representation in the training and testing data sets. If a larger sample size is used for the data sets, the chances are the data sets will have similar distributions. As the size of the training and testing data sets are decreased by number of records, it is much more likely that the data sets will have a biased distribution of drive times of one versus the other. The present invention recognizes such discrepancies and provides a mechanism by which recommendations for increasing sample size may be made.

It is important to note that while the present invention has been described in the context of a fully functioning data processing system, those of ordinary skill in the art will appreciate that the processes of the present invention are capable of being distributed in the form of a computer readable medium of instructions and a variety of forms and that the present invention applies equally regardless of the particular type of signal bearing media actually used to carry out the distribution. Examples of computer readable media include recordable-type media such a floppy disc, a hard disk drive, a RAM, and CD-ROMs and transmission-type media such as digital and analog communications links.



Docket No. RSW920000182US1

The description of the present invention has been presented for purposes of illustration and description, but is not intended to be exhaustive or limited to the invention in the form disclosed. Many modifications and variations will be apparent to those of ordinary skill in the art. The embodiment was chosen and described in order to best explain the principles of the invention, the practical application, and to enable others of ordinary skill in the art to understand the invention for various embodiments with various modifications as are suited to the particular use contemplated.

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